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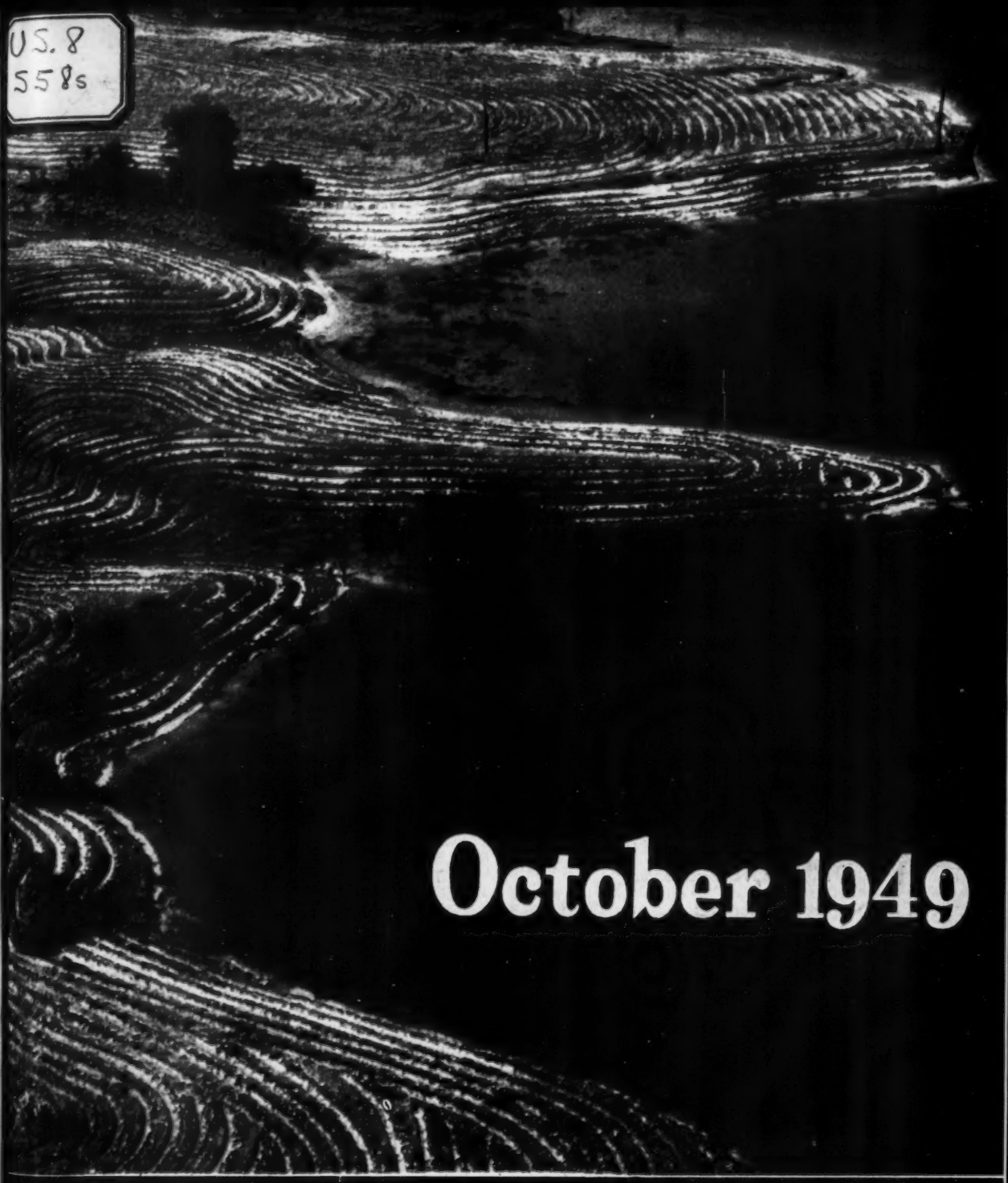

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☆ THIS MONTH ☆

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Editor
Art Work by
W. HOWARD MARTIN

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SPECIAL ISSUE.—This month we speak of water: of water in companionship with Earth and Man.

We look to the skies, the mountains, the forests, and the fields. We contemplate water quiet and contained, and water excited, raging, and uncontrolled. We note the gentle raindrop, the trickle down an irrigation ditch. We see water in laboratory and in industry.

All life, every living organism, amoeba, corn stalk, mallard, trout, eel, angleworm, electric power and transportation, every job, every ambition, every human soul upon the face of the globe, exists by blessing of water.

This issue tells but one small chapter of the story. SOIL CONSERVATION Magazine publishes the newest findings in drainage, irrigation, pond-building, sedimentation and percolation studies, flood-control progress, water-management methods, in its month-by-month coverage of the Nation's program of soil and water conservation.

THE EDITOR.

FRONT COVER.—Where land and water meet. An interesting pattern along the shores of Lake Atwood, Ohio. Under the direction of H. P. Garritt, SCS forester, young conifers are planted in contour ridges—a part of a vast reforestation program which embodies more than 46,000 acres, most of which were abandoned farm land within the Muskingum Watershed Conservancy District. More than 2,000,000 young conifers, principally red pine, white pine, and pitch pine, have already been planted as part of the district's program to bring back the forests of yesterday to northeastern Ohio and to insure a prosperous future. Photographer: Herrin F. Culver.

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ALL LIFE DEPENDS ON WATER

By DANIEL L. SECKINGER

AN EARLY description of the appearance of water in the universe is found in the story of creation (Genesis I:9–14), where it is stated that the waters were "gathered together unto one place," called the seas, and after this the "dry land" appeared. How long after the waters receded before life began on the land no one knows, but there is geological and other evidence that there was an orderly sequence of development culminating in the appearance of man. Throughout the development of all forms of organic life, there has been absolute dependence upon water for growth and maintenance; its requirements for all forms of life are universal. With the appearance of organic life upon the land, the relationship between land and water became fully established.

In addition to land and water, a third element of great importance to life is the air, which makes available oxygen and nitrogen, gaseous chemicals essential for metabolism and growth, and also radiant and electrical energy, essential to the spark of life. Without the latter, there would be no life on this planet. The physical universe would consist of desolate wastes of inanimate rocks, barren soils, and water.

Nature has provided ample amounts of land, water, and air for the propagation and maintenance of all forms of life. When America was discovered, our soils were virgin because the Indian had no need for extensive agriculture, and historically this is true of a number of ancient civilizations who thrived for a while on erstwhile virgin soils now long since abandoned to become arid desert wastes.

Man, like the pathogenic microbe, is destructive of the substances or elements upon which he lives. He is destructive of the land upon which he thrives, and the microbe is destructive of living tissues. Pathological changes take place in both instances which make future living or existence for the microbe or man difficult or impossible. It is conceivable and even possible that the devastating effects of our present or future generations will so alter the land that it will not support life. The poet Byron immortalized in verse the ravages of man upon the land: "Man marks the shore with ravage but his control stops with the deep," which is another way of saying that man destroys the land upon which he lives, but he cannot destroy the ocean because he cannot live in it. It is generally true also that man cannot destroy the air because of its vastness, although in some instances he has become a polluting factor that from a public health point of view seriously affects the health of certain villages and cities. The nuisance factor of man's ravage of the air is even more extensive because it is applied more widely.

The only difference between man and the pathological microbe as a factor of self-destruction is that man has intelligence; he is able to measure the extent and duration of his destruction. He knows, for instance, that one time there flourished about the valleys of the Tigris and Euphrates virile civilizations that disappeared because of wanton soil erosion practices. On the other hand the germ of tuberculosis, by way of illustration, invades and ruthlessly destroys the body upon which it lives, eventually to be destroyed itself upon the death or recovery of the individual, without knowledge of the injury and destruction it creates. The only hope of survival of the microbe is that it will become implanted in another being where the process of destruction will be repeated. Man's hope of survival in the past to a large extent has also been his ability to invade new and productive virgin soils. There are, however, no new, virgin soils to be conquered and ravished by man. He must depend upon experience and intelligence to extricate and free himself from the dangers of extensive land destruction.

In the evaluation of water, land, and air in the processes of life, it appears the critical point of approach for us pivots about water and the land. The air is free and bounteous and not under direction or control of man to any large extent. Water is also as boundless as the ocean itself, but

NOTE.—The author, who holds the degrees of A. M., M. D., and Dr. P. H., is assistant health officer, coordinator, health and hospitals, District of Columbia Health Department; member of the Interstate Commission on the Potomac River Basin for the District of Columbia, and chairman of the Land Committee.

water in the ocean, without its revitalizing and rejuvenating effects upon the land, would be valueless.

The relationship between land and water is, therefore, all important and vital to all forms of life upon the land. If nature provided ample amounts of water, and no more, at the right time, the problems of deserts, dismal swamps, destructive hurricanes and floods, soil erosion and leaching, would vanish from the earth.

Nature, however, cannot supply just the right amount of rainfall at just the right time for every square foot or even every square mile of land, but she attempts to furnish barriers and buttresses against floods and drought in the form of forests, lakes, rivers, underground water, vegetation, and humus. It is only necessary to visit some primeval forest to appreciate nature's safeguards in holding and filtering rainfall. Here, even during rainy seasons streams flow in almost pristine clearness due to forest and other vegetative effects in the process of filtration and the prevention of too rapid runoff. The end result is the provision of ample food and water supplies for animals and plants. Each, in turn, has its peculiar effect upon other forms of life, and finally returns as nitrogen in an ever-recurring cycle for the continuation of life on this planet. In such a setting, each product of nature plays its own peculiar role in the economy of life. Even the discarded antlers of the wild stag furnish essential minerals to rodents and other small animals.

Of the three elements—land, air, and water—water is most malleable and admirably adapted to the uses of man. It has been described as "a gentle servant or a monster." It provides contentment for man in the gently flowing rain, the restful quietude of sylvan verdure and babbling brooks, the tint of the rainbow and kaleidoscopic skies. It is a balm to the fevered brow, a palliative against pain and myriads of other human ills. Gently and quietly during the night it soothes, bathes, and revitalizes tired and debilitated tissues and vital organs; it promotes sleep; gathers, transports, and discharges harmful toxins and human wastes. Surely and beyond any shadow of doubt its beneficence is boundless, incomparable, and beyond description by tongue or pen. It is as imponderable as life itself, boundless as the oceans, gentle as the breezes and the raindrop, but at the same time, dynamic beyond description. Its demands of man, who regards it on the hillside, are not beyond his power to comprehend or conform. It conforms itself to a forest and hillside pattern generally within the realm of human knowledge to appropriate and use. When abused, however, it is relentless in its retaliation, deadly destructive in its force and rampage, from erstwhile forest glen to the ocean. At such times, as raging floods, it assumes monster proportions, and like an infuriated and prodded giant appears bent upon the destruction of the handiwork it has created.

To add insult to injury, man not only provides for erosion and hapless, devastating floods by careless agricultural methods, but dumps waste products of industry and human sewage into rivers, lakes, and the ocean itself, and nonchalantly affirms that water in time will purify itself. It is fortunate indeed that it has this property, but the time interval between the points of pollution and purification is in most instances too long, too destructive of property, too costly, and too hazardous to health. The water-borne epidemics of typhoid fever during the past half century testify grimly of man's inhumanity to himself and to our streams. In order to free himself temporarily of human wastes, without forethought or caution, he dumped typhoid-laden sewage into our lakes and rivers, with catastrophic results. It has taken more than a quarter of a century to extricate ourselves partially from this obnoxious practice and menace to health.

As the population of the country increases and agriculture is extended to meet the demand, another danger lurks upon the horizon. "Hidden hunger," or qualitative dietary deficiency, confronts men of medicine and agriculture. Our virgin soils contained the necessary minerals and vitamins for intra-uterine life, as well as from birth to the grave. This is no longer true. Serious nutritional deficiencies occur out of exhausted and eroded soils for plants, animals, and man. Man in the last analysis is most deeply involved and concerned, for he lives on plants and animals. By way of illustration, a child cannot obtain sufficient calcium to develop sturdy, bony framework if its vegetable diet is deficient in calcium because of lack of this element in the soil upon which the vegetable grows. Neither can a cow provide calcium in milk if she feeds upon grass grown upon a soil deficient in calcium. Calcium, phosphorus, and potassium have long been recognized as essential soil minerals, but more recently iron, copper, zinc, chlorine, sodium, magnesium, manganese, silver,

boron, nickel, aluminum, arsenic, fluorine, and iodine have been added to the list as "trace" elements, because they are vitally essential even though they are required in minute amounts.

Fortunately, in this country the problems of nutrition and soil and water conservation have been recognized before it is too late. The Department of Agriculture, in all of its important branches and relationships, is fully cognizant and operative against the dangers of soil exhaustion and erosion, brought about by improper cultivation methods, lack of forest and wildlife protection, and an inadequate understanding of the relationship that exists between soil and water. Its efforts and influence in the community is tremendous. Friends of the Land, a nonprofit, nonpartisan society for the conservation of soil, rain, and man, met in Washington 9 years ago, because it was "felt there was a job to be done" which "could be achieved only through information, knowledge, and education." In this capacity it is a power for good throughout the country. The anti-pollution bill, passed by the Eightieth Congress, and signed by the President, will bear directly upon municipal, industrial, and soil pollution problems that affect our streams. River compacts such as the Potomac River Commission, and large metropolitan newspapers, are also in the vanguard of the movement to free our streams of harmful organic and inorganic wastes.

The outlook for immediate amelioration is hopeful and promising, but the movement must be brought forcibly to every home and fireside, whether rural or urban, producer or consumer, for every citizen is vitally concerned in the movement to bring health, happiness, and longevity.

The Biblical injunction that the sluggard should go to the ant and consider her ways in its implications is as pertinent in water management and soil conservation matters today as it was thousands of years ago. We should consider the raindrop from every angle and point of view—its potentialities for good as it unites with fellow raindrops on the sylvan hillside—and follow its progress to a small stream or river. If it emerges as a gently flowing stream of glistening clearness even during a rainy season, the purposes of nature have been fully accomplished. On the contrary, if it is on rampage, turbid and soil-laden, the purposes of nature have been thwarted. In an agricultural community, can this be prevented? That is the problem. But the way of the raindrop is clearly indicated and defined, and the lessons we learn from it and the practices we adopt are tantamount to our national health and existence.

GROUND-WATER SITUATION OF THE UNITED STATES

By GARALD G. PARKER

ADMITTEDLY, the title of this paper sounds ambitious, and to write a comprehensive report on the ground-water situation of the United States would require far more space than is available here; nonetheless, an attempt will be made to canvass the subject broadly and to touch briefly upon the significant points.

More and more we hear talk about, and read alarming reports of, the imminent failure of our ground-water resources. It has been reported that ground-water depletion is well along the way and that, with reports of declining water levels all over the country, it is only a matter of time until the wells will all be dry. What is the actual situation? How much truth is there in these alarming reports? In the following paragraphs I shall attempt briefly to lay a foundation for, and arrive at a general answer to, these important questions. Before doing so, however, let us nail down one important fact. For the country as a whole there is no progressive decline of the water table. Where a decline has occurred, whether in a heavily pumped industrial or irrigated district or on an individual farm, there are definite, ascertainable reasons for it which can be identified by scientific investigation, and economically feasible solutions can be developed for nearly every such problem. Such a solution may range from large-scale redistribution of pumpage or development of a supplemental water supply, in the case of a heavily pumped district, to simple deepening of a farm

NOTE.—The author is geologist, ground water branch, water resources division, U. S. Geological Survey, Washington, D. C. This article is published by permission of the Director of the U. S. Geological Survey.

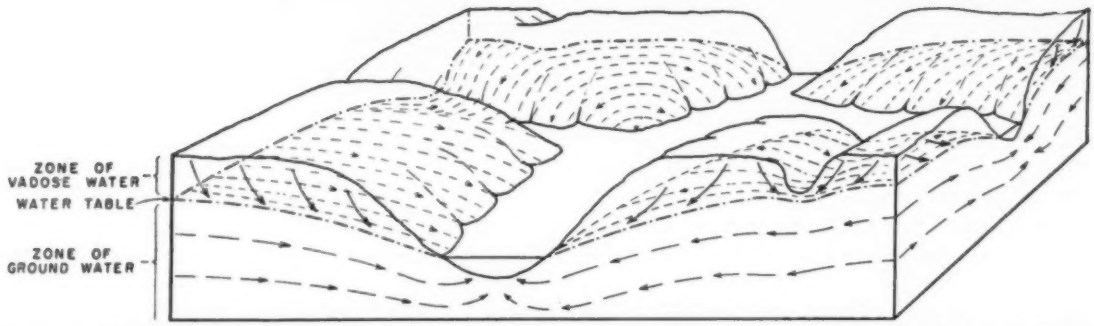

Figure 1. Idealized block diagram showing relation of water table to land surface. (Adapted after Longwell, Knopf and Flint, Physical Geology, John Wiley & Sons. By permission of publishers.)

well that was not deep enough initially to allow for the seasonal or dry-year lowering of the water table that is an integral part of the ground-water picture everywhere.

That we may properly understand the ground-water situation of the United States, it may be well to review briefly the occurrence of our ground-water resources.

The ultimate source of ground water is precipitation and, depending upon conditions of precipitation (intensity, areal distribution, etc.) and topography and geology, the ground-water resources are renewable—but only within limits, for in any given area the supply can be withdrawn more rapidly than it is replenished and thus can be depleted. Ground water is, in most places, constantly moving from higher to lower altitudes; it travels down gradient under pressure in artesian systems or by simple gravity flow under water-table conditions in nonartesian systems.

Figure 1 shows the way in which ground water typically occurs under water-table conditions. Figure 2 is a typical cross section in which a nonartesian aquifer (water-bearing formation) is underlain by a confined or artesian aquifer. Figure 3 shows an example of such conditions, at Fort Pierce, Fla., where both nonartesian and artesian aquifers are present, and where pumping the artesian wells lowers the artesian-pressure surface but does not affect the water table.

The range in ground-water conditions in the United States is as great as might be expected on the basis of the wide ranges in climate, topography, geology, permeability of rocks, and the extent to which the individual aquifers are exposed at the surface to recharge from precipitation or stream flow. Thus, we have areas of dry climate and rocks of low permeability where ground water is very scarce, such as parts of the Dakotas and of the plateaus of Utah; areas having a humid climate but still having rocks of low permeability, such as parts of southern Illinois; areas of permeable and productive sediments but having a dry climate and a very low rate of recharge, such as the High Plains of Texas; areas having both permeable rocks and a wet climate and thus a very large ground-water supply, such as the Miami, Fla., area and certain glaciated areas in the Midwest and Pacific Northwest; there are all conceivable gradations among these conditions. Among the most productive ground-water regions are the Atlantic and Gulf Coastal Plains; the north central area of thick glacial deposits, especially Michigan and northern Indiana; parts of the northern High Plains in Nebraska; those alluvial basins in the West which are adjacent to high mountains that receive abundant precipitation; and parts of the glaciated and lava-rock areas of the Pacific Northwest. Among the least productive areas are the unglaciated parts of the midcontinent region extending from Kentucky and Tennessee to the eastern edge of the High Plains; parts of the northern Great Plains in the Dakotas and Montana, and the low mountains and high plateaus of the arid West.

All in all, the United States is blessed with enormous ground-water resources, though the geographic distribution is not so uniform as would be desirable, and it is this factor rather than an over-all shortage of water which is responsible for our water problems.

To determine the status of the Nation's ground-water resources, the United States Geological Survey at present maintains about 50 field offices and suboffices in various parts of the United States and, as part of the investigations, makes periodic water-

level measurements in more than 7,000 wells. These offices are usually set up through cooperative agreements with the States, or sometimes with smaller political subdivisions. Funds have never been adequate to make a complete, integrated, and continuing Nation-wide study of our ground-water resources; for that reason, and also owing to the nature of the Federal-State investigations, many of which are directed toward restricted though nonetheless important problems, comprehensive coverage of our Nation's ground-water supplies does not exist. No individual or organization has a quantitative answer to all the ground-water problems of this country.

However, this is not to say that little is known, or that we cannot make intelligent appraisals of our problems. As a result of the United States Geological Survey investigations to date, approximately 2,000 technical and scientific reports have been published. These cover small to large areas, both generalized areal and detailed quantitative investigations, areas within the continental United States and the territories, methods of procedure, and many related subjects. New techniques of investigation are constantly being developed. Among those developed in recent years or being developed now are mathematical procedures for using the results of pumping tests on wells to predict the long-term availability of specific quantities of water under specified conditions of withdrawal; test-drilling techniques that yield the maximum information at the least cost; use of geophysical instruments to supplement test drilling; development of electrical-model and other

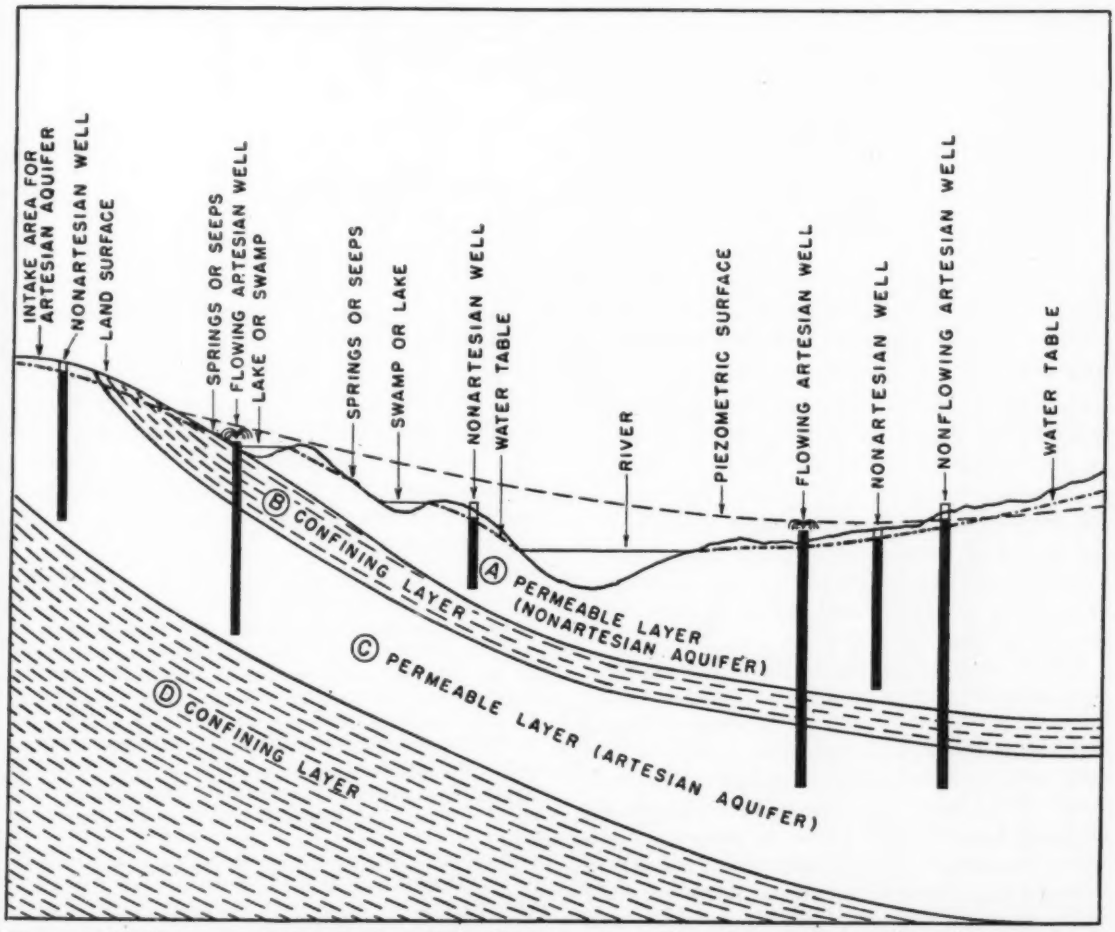

Figure 2. Idealized cross section showing relation between water table and piezometric surface of artesian water in an area with geologic structure similar to that of Kissimmee Valley, Fla.

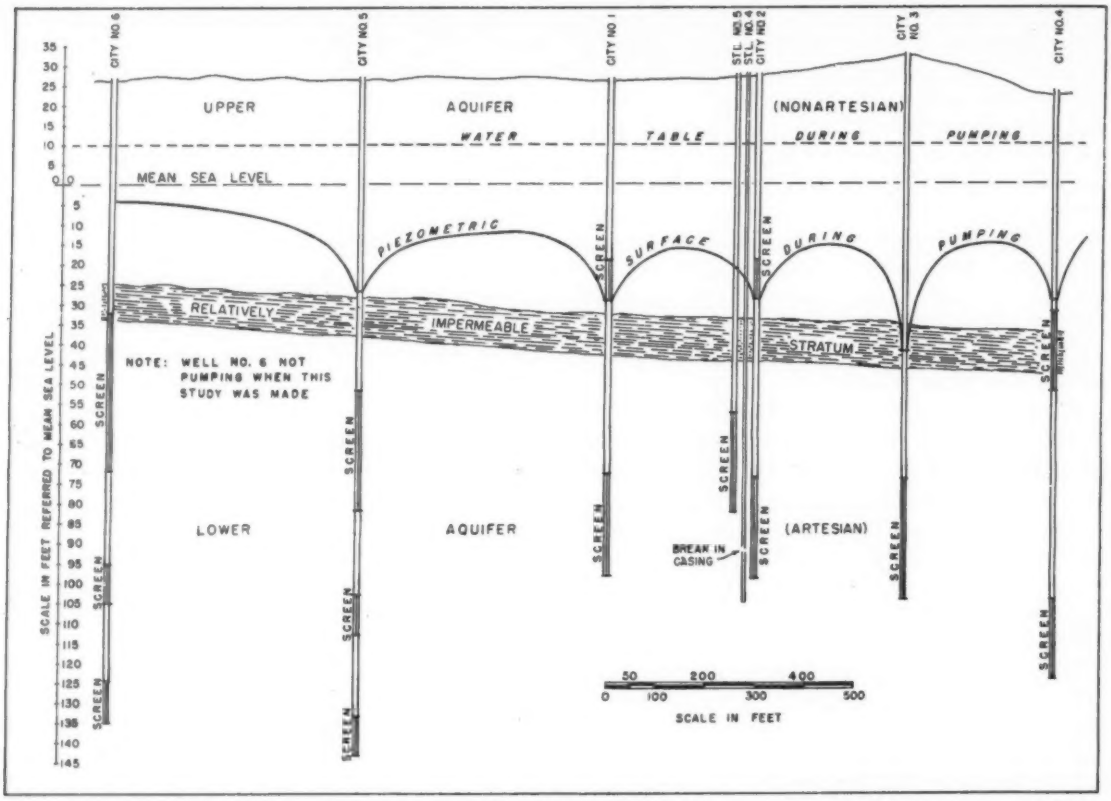

Figure 3. Generalized north-south cross section through Fort Pierce, Fla., municipal well field showing geologic formations and ground-water levels on June 6, 1944.

laboratory methods of studying problems too complex to be treated by mathematical analysis of pumping-test results; studies of the mechanics of unsaturated ground-water movement in relation to the occurrence and amount of natural recharge; and studies of the practicability of artificial recharge and of inducing infiltration from streams by pumping from nearby wells. All in all, we have a very substantial body of knowledge about our ground-water resources.

Figure 4 is a map of the United States showing areas of known heavy ground-water withdrawals; areas for which substantial ground-water data are available; areas in which quantitative studies have been made; and estimated pumpage by States in 1945. The map is not claimed to be absolutely accurate, for even such a term as "heavy ground-water pumpage" is not wholly objective. However, the map does serve a valuable purpose in that it indicates plainly areas lacking in study, and shows by comparison the relative importance of ground-water development in the several States.

In many parts of the country, especially in the arid and semiarid West, surface-water supplies have been largely developed—in fact, in some cases overdeveloped. In these areas the remaining undeveloped ground water is the only source of new water supplies.

During the past 10 years, ground-water consumption in the United States had about doubled and is now in excess of 20 billion gallons daily. Assuming an average cost of production of 5 cents a thousand gallons (about $16 per acre-foot), this amounts to more than a million dollars a day spent for ground water. Of the total of 20 billion gallons a day estimated for 1945, irrigation in the West accounted for 9 billion gallons a day and irrigation in Arkansas, Louisiana, and Florida for 1 billion gallons a day. Industrial use required 5 billion, municipal use (excluding industrial) 3 billion, and rural use 2 billion.

Irrigation with ground water is rapidly increasing, even in the humid East. In some areas, however, including such important ones as central Arizona, the southern High Plains of Texas, the Central Valley of California, and the West Basin near Los Angeles, serious ground-water short-

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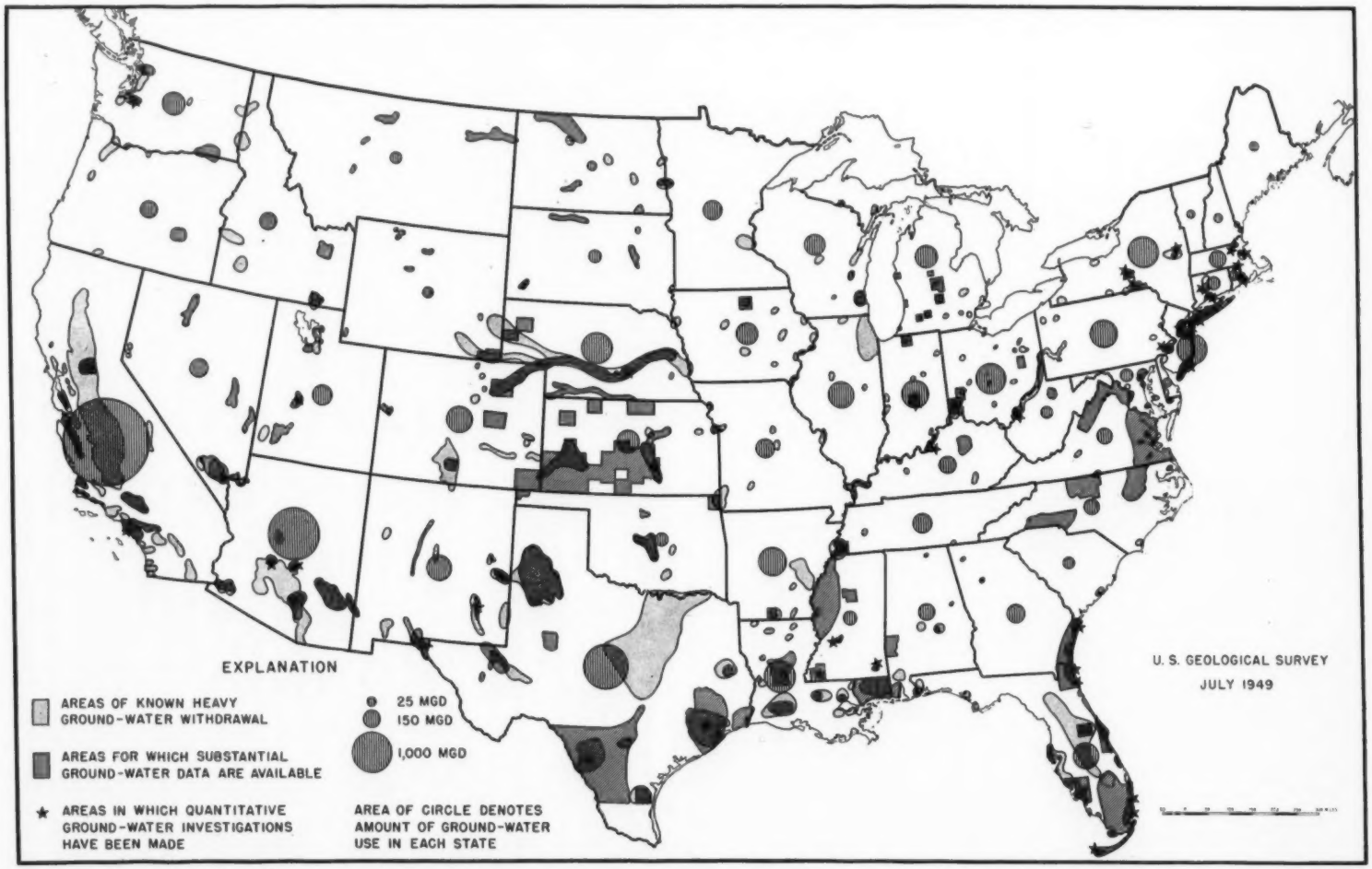
EXPLANATION
AREAS OF KNOWN HEAVY GROUND-WATER WITHDRAWAL
AREAS FOR WHICH SUBSTANTIAL GROUND-WATER DATA ARE AVAILABLE
AREAS IN WHICH QUANTITATIVE GROUND-WATER INVESTIGATIONS HAVE BEEN MADE
25 MGD
150 MGD
1,000 MGD
AREA OF CIRCLE DENOTES AMOUNT OF GROUND-WATER USE IN EACH STATE
U. S. GEOLOGICAL SURVEY
JULY 1949

Figure 4. Map of the United States showing areas of known heavy ground-water withdrawal; areas for which substantial ground-water data are available; areas in which quantitative investigations have been made; estimated pumpage by States in 1945.

ages are presenting problems difficult to solve. In some areas, such as Arizona, where surface water formerly furnished essentially all irrigation supplies, ground water now is the chief source. Arizona, in 1945, used approximately 4 million acre-feet of water for crop irrigation. Of this, slightly more than 50 percent came from groundwater sources. In 1948 the total was about 4½ million and the ground-water percentage increased to about 70. Here, as in some other areas, pumpage exceeds the natural supply. This is indicated by continued decline of groundwater levels, amounting to an average of 8 feet in central Arizona during 1948 alone, on top of the decline in previous years. In certain local areas the decline in 1948 was as great as 21 feet; the Deer Valley area has shown a total decline since 1941 of more than 100 feet. And with this decline in level is a constantly increasing salt content in the ground water in the lower parts of some basins, resulting from lack of sufficient outflow to keep the salt flushed out.

Another area worthy of more than passing mention is the Texas High Plains south of Amarillo, where irrigation from wells has recently expanded at a faster rate than in any other area in the United States. In 1934 about 300 wells irrigated 16,000 acres, but by 1948 this had increased to 10,500 wells irrigating more than 1 million acres. The ground water comes from sands constituting an enormous ground-water storage reservoir which has a very low annual recharge. The water here is being "mined"—that is, removed at a rate many times the recharge, and it is but a question of time until the yield will drop off to uneconomic amounts as the water levels decline in ever-larger areas. The problem is not alone that of the hydrologist who determines the balance between input and outgo, and thus derives the "safe yield." It is also a problem for economists, businessmen, statesmen, and philosophers, who must decide how long the stored water should be made to last and the conditions of its withdrawal. Hitherto most legal concepts have been based on the assumption that withdrawal of ground water must be held within the limits of the perennial yield, but the High Plains case indicates that under certain conditions this principle may have to be modified.

Industrial and municipal use of water, especially during World War II, created numerous problems and much alarm. Miami, Fla., lost two well fields and thousands of privately owned wells to salt-water encroachment before it was determined that the cause was drainage canals which had so lowered coastal water levels as to induce seawater encroachment because the balance between salt water and fresh water had been upset. Slight raising of the water table by control works in the tidal canals will solve the problem of salt-water encroachment in the Miami area. Louisville, Ky., during the war found its groundwater level receding at an alarming rate. Quantitative studies of the aquifer indicated the amount of pumping to be about 20 million gallons a day more than the recharge. Industries voluntarily effected many economies in groundwater pumping, and at two plants cold surface water was artificially recharged to the aquifer during the winter, then used during the summer when surface water was too warm. Through knowledge of the industrial needs, adequate study of the hydrology of the aquifer, and teamwork among the users, the Louisville problem was solved, and the total withdrawal is now adjusted to the recharge.

Numerous other situations might be cited; however, these will suffice to show the nature of some of the problems and remedies. The main points to be stressed are, first, that many of our serious ground-water problems can be solved within economic limits through adequate hydrologic investigations involving all the techniques of a vigorously developing young science; and, second, that it is possible by means of adequate basic studies to prevent problems from arising, by pointing out the limitations of a supply early in the game, and it is cheaper to do so than to wait until a serious problem has arisen and then perhaps to find that a valuable aquifer has been irretievably despoiled.

In concluding, it may be stated briefly that, in general, there is no present danger of depleting the ground-water supplies of this Nation, except locally. And, even in local areas, much can be done to prevent disaster by intelligent use of the aquifers once their hydrologic characteristics are known. Over short periods of time ground-water reservoirs can be overdrawn without serious results. During times of unusually heavy precipitation above-average replenishment of the ground water will postpone the day of reckoning resulting from overdevelopment. But we would be shortsighted indeed if we failed to recognize that, to protect the heritage that rightfully belongs to the next generation, long-range solutions to these problems must be developed.

AN INFILTRATION STUDY

By GLENN K. RULE

COTTON hulls, or "gin trash," may not have much apparent relation to the water problems of California. Suprisingly, however, this waste material leads all others thus far tried as a surface treatment to hasten the taking up of water by the soil in a way that leads it on down into the underground reservoir.

This is significant news to thousands of California farmers who are obliged to pump water at increasing expense from deeper and deeper depths as the level of the underground water supply drops with use. Research workers of the Soil Conservation Service have derived much encouragement from their discovery of this method of coaxing

NOTE.—The author, executive assistant to the chief of the Soil Conservation Service, based this article on data supplied by A. T. Mitchelson, State project supervisor, Division of Irrigation and Water Conservation, Soil Conservation Service, Berkeley, Calif.

large quantities of water into the underground strata to replace ground water removed by heavy pumping for irrigation.

While legal rights to water from stream flow provide some assurance of a water supply for those who own such rights, a far greater problem, in the larger perspective, relates to the increasing number of water users who depend on water pumped from failing underground sources. In some of the most adversely affected areas in the upper San Joaquin Valley, for example, the ground-water level is said to have dropped in places from around 50 to 200 feet between 1921 and 1939. I am told that this has caused the abandonment of nearly 50,000 acres of once highly productive land.

According to local information, when farmers began sinking wells near Wasco about 1910, it was not unusual for them to reach water at depths of 20 to 25 feet. Now, by contrast, most of them are obliged to lift water around 125 feet or more. Obviously, this means that more water is coming out of these natural underground storage reservoirs than is going into them.

Background—settling or infiltration basins at Wasco, Calif. Soil in each is treated with an agricultural waste such as cotton hulls, corn stalks, or straw. Water is measured into each tank, object being to determine which treatment gives best infiltration rate. Foreground—apparatus used to check on horizontal movement of water.

This situation causes farmers and landowners to cast envious eyes on excess flood water that annually runs to the sea as waste. This raises the question: Can such waste water be spread over the land and induced to enter the underground storage spaces fast enough to raise the water table or, at least, to prevent it from dropping still farther?

Water spreading on detrital cone of Upper Santa Ana River, San Bernardino County, Calif. Earth-rock dams are formed on slopes just high enough to back water to downstream toe of next higher dam, thus increasing wetted area.

Of course, there are no quick answers to this question. Much has been learned but far more needs to be known. First of all, the farmer must be assured that there is a satisfactory underground reservoir of water available and suitable for pumping and that the reservoir can be recharged by water spreading.

Much of our knowledge with respect to underground storage is based on experience with coarse-textured soils. One of the first recorded attempts to spread water for underground recharge was made near Denver, Colo., on the outwash soil of Cherry Creek, in 1889, by the Denver Union Water Co. Later, water was again successfully saved by spreading it on the detrital cone of Santiago Creek in southern California. A little later the same practice was successfully used near the mouth of the Santa Ana River. These later projects have since been enlarged and improved and the general practice of water spreading in much of southern California stems from these early trials.

Still later, research work was started on the detrital cone of the San Gabriel River in Los Angeles County. But in the '30's, as earlier, water engineers did not fully sense the wide difference in soils with respect to the amount of water they could take up. As a consequence, this study was concentrated on several other factors which, though related and important, did not throw adequate light on the problem of storing water in the ground under diversified soil and topographic conditions. Meanwhile, irrigation and other pumps

(*Continued on page 65*)

FIGHTING FLOODS AT THEIR SOURCE

By L. G. SIGNELL

WHAT is done with the water? What happens to the land? The answers to these questions are an index to the success of watershed methods of flood control.

Here, upstream, along the tiny tributaries, spread out on valley slopes, is the logical beginning of the comprehensive soil conservation plan to minimize the hazards of destructive waters. The program is not simple. Many people, many organizations, many government agencies are concerned. There is a wide variety of courses of action from which to choose.

Accordingly, any review of flood-control accomplishments needs to take into account the sometimes seemingly unproductive but nonetheless essential steps leading to the installation, operation, and maintenance of specific measures on the watersheds.

A progress report is expected to summarize principal accomplishments in terms of measurable units of work. The change in aspect and extent of SCS activities in flood control since World War II contrasted to those before the war, however, have been so pronounced that this report might well relate the developments of the past 3 years to those of the prior period. Also, it seems desirable to recount the evolution that has taken place in the matter of concept.

In 1936 investigations were begun. By World War II, survey reports had been completed on 11 watersheds. These reports recommended works of improvement and were transmitted to Congress. Seven of them at that time found insufficient benefits to justify federal participation in watershed treatment under the flood-control authority. Surveys were in various stages of completion on some 32 other watersheds when the war necessitated suspension of the work. In addition, the preliminary examination had been made of 124 watersheds in which sufficient flood damages were apparent to warrant recommending the more complete analysis accorded by surveys.

This early period, as would be expected, was given over to learning what this new arm of the Service was to do. Top technicians were assigned to develop techniques for evaluating flood damages, and for tracing the origin of these damages. Methods were formulated for appraising the physical benefits of measures proposed for retardation of runoff and waterflow and for soil erosion prevention at the source to reduce flood damages. Ways were worked out to estimate costs of installing and maintaining practices, as related to the expected monetary and other benefits. Since federal assistance to carry out flood-control operations was to be determined in the Congress on a watershed basis, each report reecived close scrutiny by committees in the

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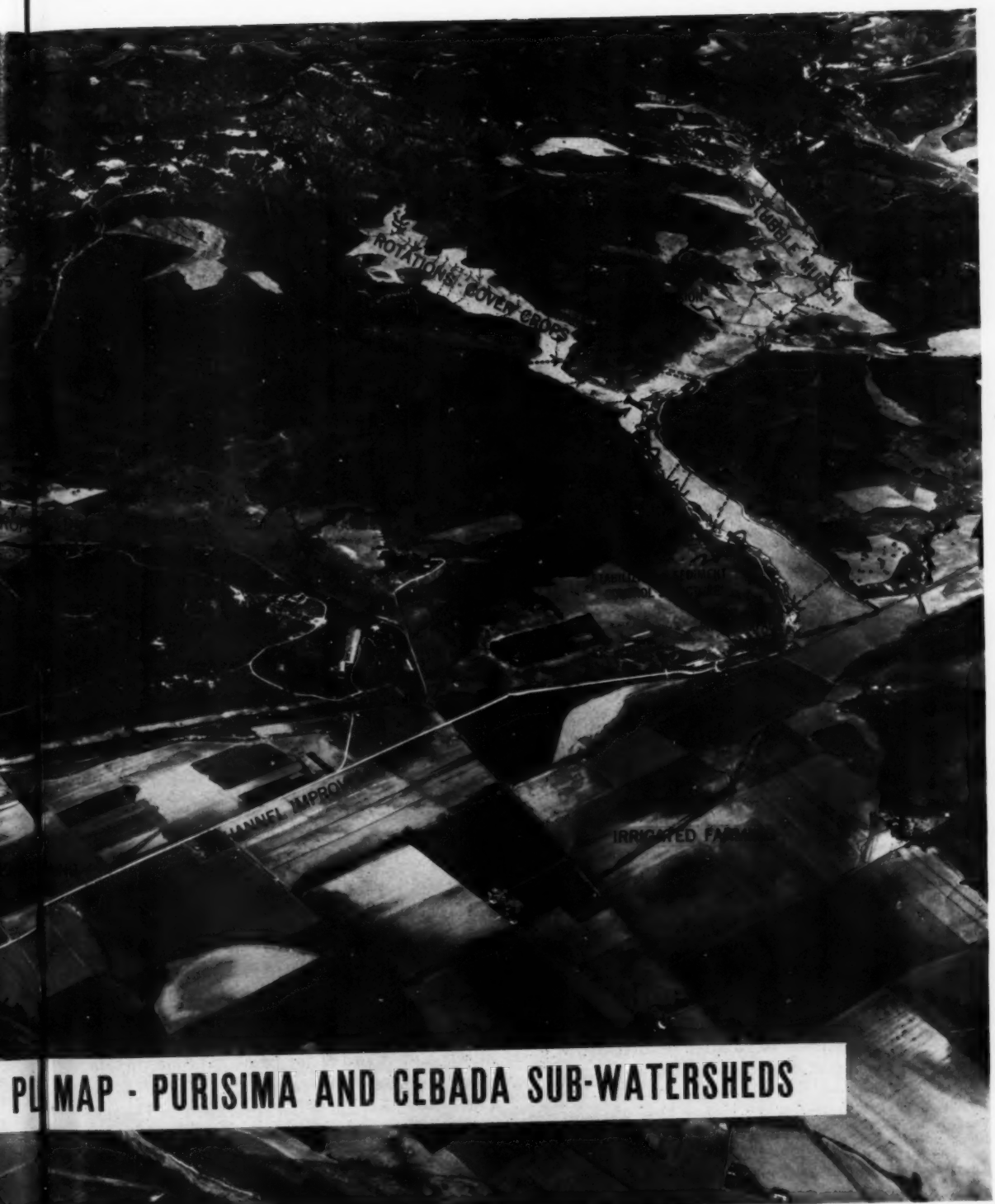


PL MAP - PURISIMA AND CEBADA SUB-WATERSHEDS

Service and jointly with representatives of participating bureaus in the Department of Agriculture. They were also reviewed by the States, the Army Corps of Engineers, the Bureau of Reclamation, and other interested agencies.

Out of this sorting period came completed survey reports for 11 watersheds in which the recommended works of improvement were authorized by Congress for federal participation in application. It yielded experiences and procedures invaluable when surveys were resumed in fiscal year 1946.

Although the war was still going on when the 1944 Flood Control Act was passed, Congress provided (in sec. 13) "that the necessary plans and preliminary work may be prosecuted during the war with funds from appropriations heretofore or hereafter made for such works so as to be ready for rapid inauguration of postwar construction," and "that when the existing critical situation with respect to materials, equipment and manpower no longer exists and in any event not later than immediately following the cessation of hostilities in the present war, the projects herein [1] shall be initiated as expeditiously and prosecuted as vigorously as may be consistent with budgetary requirements."

The Department of Agriculture had a long way to go to fulfill this directive. The estimated cost of federal participation in the 11 watersheds totaled nearly $90,000,000 (prewar prices). The works of improvement were recommended in the survey reports to be installed over periods ranging from 10 to 24 years depending on the kind of measures proposed in the respective watersheds and the expected rate with which local cooperation would materialize.

Where to begin, what to install, who would participate on specific jobs, what rate should be scheduled for the different types of work and how the entire activity would be tied together to achieve the flood-control purposes were all key questions which needed to be worked out before a logical basis could be established for requesting allotment of funds and for carrying out operations.

An early decision was to go after results; therefore, operations would be concentrated on retarding runoff and waterflow in selected subwatersheds. Erosion-prevention measures would aim at reducing flood water and sediment damages. There were no illusions as to the difficulty of this task; it involved the cooperation of hundreds of landowners and operators. It dealt with the installation of many and interrelated conservation practices and flood-control measures with both vegetative and mechanical means to be utilized fully.

An allotment was made in fiscal year 1946, from reserve funds, to make "necessary plans and preliminary work." Governing bodies of soil conservation districts provided local leadership. District supervisors usually saw to it that the subwatershed flood-control work plan was incorporated in the district work plan—the logical chart for showing what is to be done, where, by whom, how and when, at what rate, and at what cost.

To get started on the right foot, to get or keep in step with the march of events, required recognition of the direction being followed in the development of major works by other departments for flood control, drainage, irrigation, water power and allied purposes, as well as the trend of operations in the soil conservation movement.

A grass-roots leader, member of a State soil conservation committee, recently reiterated the principle "a river and its tributaries constitute a unit, one living organism; you cannot affect any part of it in a substantial way without affecting all of it; you cannot control and develop it for any particular function without affecting the potentials of the other functions."

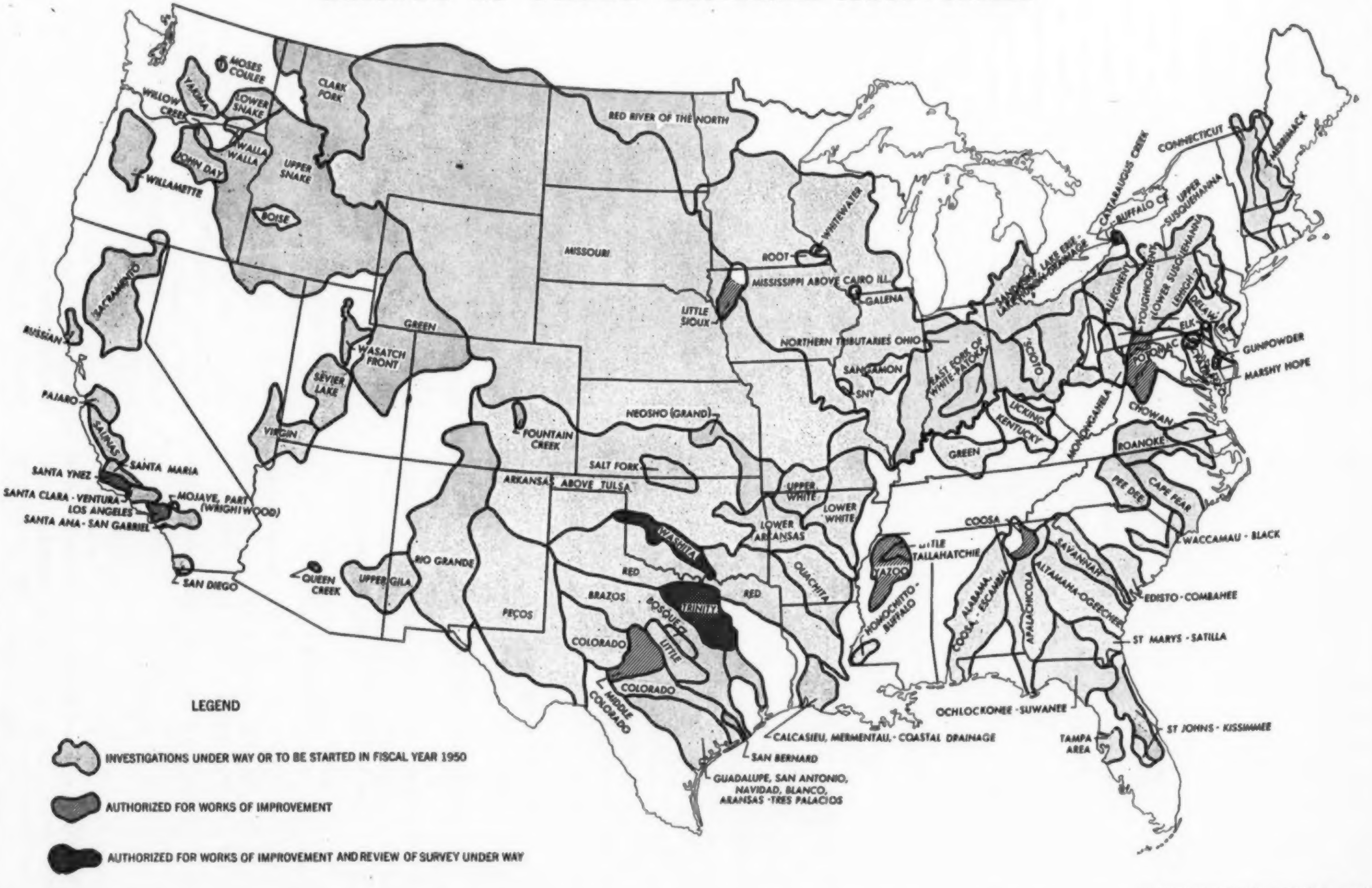
Since this concept was first stated some 15 years ago, it has enjoyed such popular acceptance that programs comprising major structural works for flood control, navigation, irrigation, land reclamation, and power have been planned on the broadest possible basis. The programs cover such river-basin systems as the Missouri, Ohio, Rio Grande, Central Valley (Calif.), and Columbia.

A good example is the Pick-Sloan plan for the Missouri Basin, in which are related the development schemes of two of the principal construction arms of the Federal Government.

A further milestone is the agreement of December 29, 1943, of the Federal Inter-Agency River Basin Committee, which provides for mutual consideration, exchange of information, and correlation of programs by the member agencies.

[1] Buffalo Creek Watershed, N. Y.; Potomac River Watershed, Va., W. Va., Md., and Pa.; Little Tallahatchie River Watershed, Miss.; Yazoo River Watershed, Miss.; Coosa River Watershed, Ga., Tenn.; Little Sioux River Watershed, Iowa; Middle Colorado River Watershed, Tex.; Trinity River Watershed, Tex.; Washita River Watershed, Okla., and Tex.; Santa Ynez River Watershed, Calif.; and Los Angeles River Watershed, Calif.

STATUS OF FLOOD CONTROL ACTIVITIES



There followed soon the formation of the Missouri Basin Inter-Agency Committee and the Columbia Basin Inter-Agency Committee to follow through in more detail the proposals for development of the resources of the respective basins.

As these basin committees got into their work, it soon became evident that an essential element was lacking. The large impounding reservoirs, floodways, navigation channels, irrigation and drainage canals were destined to function with ever-diminishing effectiveness as sediments washed in from watershed lands and tributaries.

The triple threat of land impoverishment from erosion, flood damage from frequent overflow of tributary valleys, and sedimentation in downstream works needed to be tackled on a comparable basis with the major works just referred to, in order that the whole scheme of improvements return the maximum continuous benefits. Accordingly, the watershed or subwatershed approach has taken on new and enlarged meaning.

As many will recall, the early Soil Conservation Service demonstrations were on a watershed basis. Launching of the Nation-wide conservation program began with the advent of locally organized soil conservation districts. Of necessity, this caused a temporary departure, generally speaking, from the watershed concept in furnishing technical assistance, since the districts were formed here and there as localities became ready.

Now that more than three-fourths of all farm and

WORKS OF IMPROVEMENT

Some of the principal accomplishments, as of December 31, 1948, are:

1. Small upstream floodwater-retarding reservoirs—306 for detention of 150,248 acre-feet planned; 13 completed for 2,450 acre-feet.
2. Debris basins.—1,417 planned; 285 completed.
3. Revegetation.—Grasses and legumes, 296,956 acres planned, 40,502 acres completed. Woody plantings, 34,576 acres planned; 1,213 acres completed. These figures include critical slopes and silt source areas where vegetative cover provides watershed protection.
4. Minor waterways.—80.48 miles planned; 15.93 miles completed.
5. Tributary channel stabilization.—257.6 miles planned; 5.5 miles completed.
6. Diversions.—200.3 miles planned; 31.0 miles completed.
7. Gully control.—11,534 acres planned; 260 acres completed.
8. Roadside erosion control.—914.5 miles planned; 17.2 miles completed.
9. Structures.—1,299 planned; 436 completed.

SURVEYS

As of July 1, 1949, status of watershed surveys, for which the Soil Conservation Service is responsible for report preparation, was as follows:

Reports transmitted by Chief, Soil Conservation Service, (concurred in by Chief, Forest Service) to Secretary of Agriculture:

	Date transmitted to Secretary
Pee Dee, N. C., S. C., Va.	January 5, 1949
Sny, Ill.	January 17, 1949
Queen Creek, Ariz.	February 2, 1949
Missouri, Mo., Iowa, Minn., Kans., Nebr., S. Dak., N. Dak., Mont., Wyo., and Colo.	March 25, 1949
Grand (Neosho), Ark., Kans., Mo., and Okla.	March 30, 1949
Little, Tex.	April 12, 1949
Pecos, N. Mex., Tex.	June 3, 1949

Field work completed, drafts of reports being reviewed by interested local groups, State and Federal agencies:

Arkansas, Lower, Ark., Okla.
Walla Walla, Wash., Oreg.
Whitewater, Minn.
Root, Minn.
Youghiogheny, Pa., Md., W. Va.
Galena, Wis., Ill.
Bosque, Tex.
Roanoke, Va., N. C.
Scioto, Ohio
East Fork of White and Patoka, Ind.
Sangamon, Ill.
Gila, Upper, Ariz., N. Mex.
Salt Fork, Okla., Kans.

Field work under way

Lehigh, Pa.
Savannah, S. C., N. C.
Green, Ky., Tenn.
Apalachicola, Fla., Ala., Ga.
Mississippi (above Cairo, Ill.,) Ill., Mo., Iowa, Wis., Mich., Minn.
Red, Tex., Okla., Ark., La., N. Mex.
Rio Grande, N. Mex., Tex.
Salinas, Calif.
Russian, Calif.
Moses Coulee, Wash.
Willow Creek, Oreg.
Brazos, Tex. (except Bosque and Little).

ranch lands in the United States are included within the boundaries of soil conservation districts, it is practicable to proceed again with the furnishing of technical and other federal assistance on a basin, watershed, or subwatershed basis. Experience in flood-control operations in the past 3 years has borne this out. Planning for flood-control conservation operations has been done on some 450 minor watersheds comprising more than 4,000,000 acres in the 11 authorized watersheds. The soil conservation districts (and in the Los Angeles watershed, the Los Angeles County Flood Control District also) have joined wholeheartedly in minor-watershed planning, even more so than might have been expected in the short time that has elapsed since the Guide for Flood Control Operations was issued in May 1946. The principles set forth in that memorandum have proved to be practical in application; supplemental memoranda of understanding covering the flood-control activities have been entered into by the soil conservation districts concerned and the flood-control work plans incorporated in the district work plans.

With this article is a photograph of the Purisima and Cebada subwatersheds of the Santa Ynez River watershed showing land treatment and location of water management measures included in the work plan. The plans for this area were worked out in detail with the directors of the Lompoc Soil Conservation District, and the subwatershed group of landowners and operators. A schedule for order of establishment, the amount of participation, and the responsibilities of each party for installation, operation, and maintenance was agreed upon before funds for the works of improvement were requested.

Measures are being applied in each of the 11 authorized watersheds in accordance with the carefully devised work plans. Provisions are made in the flood-control conservation farm (or ranch) plans for the measures to be applied by the landowner-operator with the flood-control assistance made available to the district. Contracts are let for such works as are beyond the capacity of individual land operators to install. As of July 1, 1949, contracts had been let as follows:

Trinity	$22,476.00
Washita	274,522.85
Little Sioux	708,707.21
Los Angeles	346,278.99

These contracts cover improvements such as small upstream floodwater-retarding reservoirs, debris basins, stream-bank protection, and other works to stabilize and improve capacity of waterways and channels to carry flood runoff.

It would be presumptuous to make predictions for next year or thereafter. Possibly the best idea of the future may be obtained from the trend in the scope of surveys, reports of which are prepared for submittal to Congress and upon which authorization for operations is based.

It has been found that the cost per square mile of making flood-control investigations varies inversely as the size of watershed or basin. The cost per unit area of the larger watershed or basin surveys is but a fraction of the cost, proportionately, of that of the small watersheds. The shift to basin-wide surveys, such as the Upper Mississippi, Rio Grande, Red, and so on, is one of the significant developments in flood-control procedures. The saving in time, speeding the processes which lead to authorization of watershed treatment, is of equal or greater importance than the large initial saving in cost of investigations. Further, it provides a common denominator for correlating improvement programs of the Department of Agriculture, Department of the Army, Department of the Interior, and other Federal and State agencies.

Through this approach it can be expected that a more thorough, economic, and beneficial development will be made of basin resources.

AN INFILTRATION STUDY

(*Continued from page* 59)

in increasing numbers have been at work lifting water from underground reservoirs in many parts of the State. A recent count in the San Joaquin Valley indicates that perhaps as many as 40,000 pumps are in use in that locality to lift water for irrigation, domestic, and industrial uses. In three counties of this area (Kern, Madera, and Tulare) there are about 1,500,000 acres of irrigable land for which there is insufficient water to meet present requirements.

Such facts add interest and importance to the potential use of water that soon may be available for distribution from the Friant Dam, one of the key features in the development of the great Central Valley Project by the Bureau of Reclamation. This dam was built to store and divert water to the Madera and Friant-Kern Canals. Present plans call for the transportation by the Friant-Kern Canal, alone, of over 1 million acre-feet of water each year. About one-half of this supply will be used as Class 1 water; meaning that it is stored and available for immediate irrigation use. The other half will be principally present waste water, much of which, it is hoped, can be diverted for recharge of receding ground-water supplies.

The word "hoped" is used advisedly. The problem of using this potential water economically and efficiently has furrowed the brows of many farmers and technicians who have considered and worked on the problem.

Recent experiments, until this one near Bakersfield, were none too promising. The North Kern Water Storage District, in an experiment started in 1936 in Kern County, found that percolation rates of water applied continuously on undisturbed soils declined after a few weeks below the point of practicability. Literature of the time showed that considerable work was under way on

infiltration, but most of it was related to the infiltration of rainfall or irrigation water to the root zone of plants. It means that water was applied for relatively short periods of time—entirely too short for the recharge of deep underground aquifers.

If you drive about 24 miles northwest of Bakersfield you will find two sets of ponds which represent the most recent attempts to solve the riddle of how to get more water underground, and without using all the land as a settling basin. Work at these settling ponds or basins, one near Wasco and the other near Minter Field, represents the cooperative effort of the Soil Conservation Service, the Bureau of Reclamation, the State Division of Water Resources, and Kern County Land Company to come up with a satisfactory solution. While these structures are called ponds or basins, they really are simply wood structures, each enclosing an area of one-hundredth of an acre. Each basin is treated differently from the others, except that a known quantity of water is applied to each. The soil in each pond is treated with some agricultural waste material such as corn stalks, straw, cotton boll hulls; or it may be seeded to one or more of the adaptable pasture grasses.

Water for the Minter group first came from the Kern River by an irrigation canal, but since operations had to be discontinued each year when canal water was not available, the basins are now served by a well drilled in 1948. The basins at Wasco have always been supplied by water pumped from wells. Both groups are now supplied and operated continuously during the same periods of time.

The most beneficial treatment so far, as already indicated, has been through the use of cotton gin trash, either disked in or allowed to float until it sinks. The beneficial effect is not immediate but requires an ageing period during which the gin trash or waste decomposes in some degree. Usually the highest percolation rates are obtained after a drying-out period of the soil, following the initial period of ageing of the applied material. Peak rates as high as 14 feet per acre per day, or 3 to 4 times those obtained on undisturbed or untreated soils, have been reached. We don't know how long one application will be beneficial, but one treated basin still shows highly beneficial results 3½ years after the application.

Other treatments than this gin waste show results of varying degrees—some negative—but because the gin trash is a waste product in the San Joaquin Valley and the results from its use are so promising, the work there has been concentrated on this treatment.

Technicians working in soils and bacteriological laboratories of SCS have not definitely determined the reasons for the increased percolation rates brought about by the use of gin trash, nor has it been determined what quantity should be applied to a given area to obtain the greatest benefit. To date, applications have been rather liberal. While gin trash is free at present, hauling and applying are fairly expensive. Field work is now going on in an attempt to determine the least amount of trash necessary to obtain the most economical benefit, and also to determine whether other materials will provide results equally beneficial.

Eventually, discovery of the reason why gin trash is so effective may open the way to the use of materials as yet not considered. Meanwhile, promotion of vegetative growth on the soil surface of the ponds has produced the next best results, but such growth has been much below the gin material in effectiveness.

While it may be too early to draw final conclusions, this much seems certain—and it is very significant—that the percolation rates obtained from soils under natural condition and not underlain by hardpan or other interfering strata can be largely increased by treatment as indicated above.

Water engineers are making no claims as to the percentage of waste water that can be usefully stored underground, but it looks very much as if this infiltration work is of great promise. This single discovery may result in savings valued at many millions of dollars annually.

SPREADING WATER FOR RECHARGE

By A. T. MITCHELSON

IT HAS been only within the last 20 years that this country and to a large extent certain other countries of the world have become soil-conscious and have awakened to the necessity of soil conservation. In the meantime great damage has been done to large areas of our most fertile agricultural lands by misuse and consequent water- and wind-erosion. Today our Nation is carrying on a comprehensive campaign of conservation of soils which seeks to make them more stable and more productive.

However, unlike the broad, nationally accepted campaign of soil conservation, there is no concerted plan for water conservation, although soil and water are the major elements of life. All activities of man are dependent on the combination and proper use of these two elements. In the past some conservation of surface water has been practiced throughout all our States by the creation of

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Aerial view of San Antonio Creek debris cone. Here is almost a complete story of water conservation by underground storage. In foreground are dams or dikes built to retard and spread water as it comes from canyon; in upper center is shown the stream bed and at top is the snowbank which feeds the stream.

storage reservoirs, but only for such specific purposes as municipal and industrial use or for the development of hydroelectric power. Again, only within the past decade have we realized that Nation-wide conservation of water is an essential feature in the orderly maintenance of the national economy. In the western or semiarid section of the United States we have been perhaps a little more daringly progressive in the development of water conservation programs. Here we consider all our projects as multipurpose enterprises, including in many cases, municipal, domestic, industrial, power, recreation, flood control, and even navigation. It is notable that in all the above we have discussed *surface* water conservation. There is to date no concerted program of conservation or maintenance of ground-water supplies—certainly not as a national program. Only in limited areas of our irrigated sections have some worthwhile efforts been made to replenish and conserve these underground supplies.

The problem common to all areas of the West is the depletion of ground-water supplies. This is particularly true in California. Utilization of ground water for irrigation in California prior to 1880 was unimportant, with the exception of Los Angeles and San Bernardino Counties where nearly 1,000 artesian wells had been developed. Today the artesian flow has ceased and in practically every one of the south coastal basins of the State the water table has been falling progressively. This is because there have been five successive years of subnormal precipitation, during which period there has been tremendous increase in irrigation demand. Ground-water uses in this area are greater than surface supplies, even though the latter include importations from the Colorado River, the Owens Valley, and the Mono Basin. Los Angeles County has for many years been the leading county in the United States in income from agricultural production, which is largely supported by irrigation from ground water. In Santa Barbara County nearly all the 60,000 acres of irrigated lands are served exclusively from ground supplies. The same is true in San Luis Obispo County, Ventura County, Mojave Valley, and Coachella Valley. In the central coastal area approximately 127,000 acres in Salinas Valley, 30,000 acres in San Benito Valley, 17,000 acres in Pajaro Valley, 130,000 acres in Santa Clara Valley, and 10,000 acres in Livermore Valley are all exclusively served from ground-water resources.

North of the Tehachapi range in the San Joaquin Valley, considered the most productive valley in the country, there are some 40,000 irrigation wells delivering water to about 2 million acres of land. Most of these wells have been sunk in the past 20 years at a cost of approximately $168,000,000. The underground water supply of this valley is being overdrawn by more than 1 million acre-feet each year and the water tables are dropping alarmingly. State authorities warn that the present overdraft of underground water is far beyond any normal amount of replenishment.

These are examples of the use and importance of ground water and its depletion in one State

alone. Reports of the United States Geological Survey indicate that the ground-water basins of Eastern, Midwestern, and Southern States are also being heavily drawn upon and are consequently being depleted.

So far we have discussed the ground-water supplies and the alarming extent at which they have been and are still being overdrawn. When a given ground-water basin has been depleted, replenishment is frequently slow. Recharge may be accomplished either by natural or by artificial means.

In the humid regions recharge generally occurs naturally and more regularly, owing to more abundant precipitation. In the western or arid regions where we have cycles of deficient precipitation, replenishment is much slower, because during these dry periods it is necessary to supplement a scant surface-water supply by increased draft on ground water to irrigate crops and satisfy domestic and industrial demands.

Fortunately, however, nature has balanced this disadvantage by providing the greater portions of the arid West with aquifers susceptible of both artificial and natural recharge. Water-bearing formations differ greatly in their capacity to transmit water and in the quantity they will yield from storage. There are, generally speaking, two distinct classes of aquifers—those with low rates of recharge and where heavy withdrawals are mostly from storage; and those with high rates of recharge, transmission, and discharge, which are therefore capable of furnishing large perennial supplies. In this article we are interested in the latter class.

Deep underground aquifers are replenished naturally by precipitation falling directly on the valley floor, by seepage from streams traversing the valleys, and, in our western country, by return water from irrigation. Good examples of natural recharge are the Mimbres Valley, N. Mex., replenished primarily by the Mimbres River; the Platte River Valley, Nebr., replenished by water of the Platte River; and the Salinas River Valley, Calif., recharged by the Salinas River. All these cases are in areas where the valley floors are underlain with deposits of gravels and sands permitting both rapid recharge and copious withdrawals, yet coming back to normal or near normal levels at the close of seasons of precipitation.

On the border line between natural recharge, or where natural recharge is aided or stimulated by artificial means, there is the case of the Madera Irrigation District, Calif., where off-season water is released from Friant Reservoir (Millerton Lake) on the San Joaquin River, to the Madera Canal of the Central Valley Project and distributed to the channels of the Fresno River and several creeks and sloughs. Flowing down the porous beds of these natural channels the released water percolates to the ground water, resulting in the maintenance of high ground-water levels although there may be pumping during the period of recharge. In this case, just enough water is released from storage to satisfy the absorptive capacity of the wetted areas.

In purely artificial recharge, the term "water spreading" is used, but this practice should not be confused with the same term when used to describe diversion of water from flood channels for the purpose of irrigating crops, forage lands, and pastures. In one case small volumes of water are applied for relatively short periods of time in order to supply adequate moisture to soils within the root zone of plants. Water spreading as we practice it in the arid zones is the application of large volumes of water over areas of porous surfaces as large as can be utilized, and holding the supply on the land as long as there is available water or as long as satisfactory percolation continues. It means diverting flood waters, or other waters which might be otherwise wasted, to deep underground aquifers for future use. This may seem to be a simple procedure, but conditions encountered in most areas where spreading is needed are complex. First, the soil surface must be porous, permitting rapid entry of the water to the successive underlying soil strata, and there should be assurance that descending soil profiles will permit rapid percolation to the place of storage. These requirements are met on the debris cones of streams of southern California, where waters rushing down the steep canyon slopes dropped their bed loads of boulders, gravel, and sand as they met the flatter slopes of the valleys. As the velocity of the streams decreased, they dropped the heavier and then the lighter materials. This gradation of coarse and finer outwash built up ideal spreading areas.

The underground reservoirs or basins are really valleys filled with recent alluvial materials. One major basin, embracing Los Angeles, Orange, and parts of San Bernardino and Riverside Counties, has a surface area of 840,000 acres and consists of 37 rather distinct deep underground aquifers. They furnish the ground-water supply for practically all the area referred to. Satisfactory surface reservoir sites in southern California are few because of the steepness of the canyons, resulting in prohibitive cost per acre-foot of storage.

While spreading water for storage underground started on a small scale in Colorado as long ago as 1889, modern spreading was first practiced in southern California in what is known as the South Coastal Basin, because there the conditions were suitable and the need for water was great. From very crude headworks or diversion structures and temporary distribution systems, the practice of spreading has become an important part of the over-all conservation program of that region, with modern structures.

Cross walls on upper portion of Cucamonga Creek spreading grounds. The walls are of wire-bound rock construction. They form basins intended to settle out debris and also spread water over floor of canyon.

About 10 years ago some minor-scale water spreading was successfuly attempted in the East. The city of East Orange, N. J., carried out a spreading program by diverting water from a brook to and over about 11 or 12 acres of absorptive land. Measurements of the flow indicated absorption of more than 3 cubic feet of water per second, or a recharge of over 2 million gallons per day. Flooding has been successfully used to recharge ground-water supplies in Arizona and also in New Mexico, and experimental spreading has been successful in Utah.

There are four general methods of spreading: (1) the basin method; (2) the furrow or ditch method; (3) the flooding method; and (4) the use of pits, shafts, or wells. The method adopted is governed by the topography of the soil surface, the general slope of the spreading area, the amount of land available, and the character of the water with respect to silt content. Some spreading systems combine two or all of these methods.

In the basin method of spreading, the water is impounded in one or a series of basins formed by dikes or banks. The basins are so arranged that the entire area between basins may be submerged during spreading operations. The dikes often follow contour lines and are provided with outflow points so that excess water in the basin highest in elevation will escape into the next lower basin. This method is generally employed where the spreading surface is irregular or where depressions or ridges occur. It is not recommended where the water for spreading contains silt or other material which will tend to seal off the previous surface of the basin.

For the furrow or ditch method of spreading, water is run at low velocity through the furrow in a manner somewhat similar to furrow irrigation. Usually the furrows or ditches are shallow with flat bottoms and are spaced close together so as to expose the maximum percolation area. The grades should be relatively light, yet steep enough to provide sufficient velocity for the water to carry silt or fines in suspension, thus preventing deposition in the ditch bed.

In the flooding method, just enough water is spread over the surface to assure complete coverage, but at a very low velocity. Experiments carried on by the Division of Irrigation over a 4-year period proved flooding to be the most efficient method. In this way the soil remains in an undisturbed state and vegetative growth, which stimulates percolation and prevents erosion, is promoted.

The fourth method of recharge—that is the pit, shaft, or well method—does not actually follow in the category of spreading but is a means of delivering water to deep underground aquifers. It is the most direct method, but also the most inefficient and costly. It is not looked upon with favor by health officers, who contend that in direct delivery of surface water of questionable quality to ground-water supplies, without filtration or other accepted treatment, an entire ground-water basin may become polluted. Several attempts have been made to utilize wells for conveying water to underground storage, reversing the purpose for which they were originally intended, but the practice has not been successful. In the process of raising water to the surface, any fines loosened in the vicinity of the perforations of the casting are drawn into it and are either carried to the surface by the pump or are settled to the bottom of the well. It is notable that practically all wells continue indefinitely to discharge some sand and fines. If the flow is reversed and the well

used for recharge purposes, the fines in the water being delivered to the well and the fines in the water-bearing material of the aquifer are forced into interstices of the material surrounding the well, thus rendering it less efficient in fulfilling its original purpose. The city of Los Angeles, in efforts to recharge some of its ground-water basins several years ago, experimented with wells and abandoned the practice.

Shafts were also experimented with but found to be too costly and quite inefficient. However, recharge by use of wells has been successfully employed in some areas of the East. In certain areas in the vicinity of New York and in the State of New Jersey minor replenishing operations have been successfully carried out by utilizing diffusion wells as a recharge medium. Presumably this method is used because of the absence of adequate spreading lands.

Furthermore, even when land is available, it is not always possible to convey water readily to underground storage without considerable research into ways and means of preparing the surface soils in order to promote infiltration. In the central coast and central valley soils of California, where water spreading is necessary to replenish the depleted underground water supply, there are more consolidated soil types—claypans and hardpans—and even adverse economic conditions to contend with. As an example, there is the San Joaquin Valley where it is inescapably necessary to spread water imported from Central Valley Project or other reservoirs to relieve the ground-water conditions described earlier in this article. The Friant-Kern Canal of the great Central Valley Project will convey water from Millertown Reservoir to irrigable lands in parts of Fresno, Tulare, and Kern Counties. There will be periods during the nonirrigating season when large volumes of stored water will be available for use in spreading operations, either by release from the main canal to irrigation canals and stream beds or for spreading water over areas suitable for infiltration and percolation to the several ground-water basins of the area.

The available spreading areas are made up of sandy loams, loams, and soils of finer texture which are incidentally lands of very high agricultural value. Field studies carried on by a cooperative research project on soils of Kern County reveal that, while initial infiltration starts off at a satisfactory rate, after a relatively short period of time the infiltration rapidly decreases. Laboratory and field studies of soil structure, bacteriological action and action of micro-organisms are now being carried on. Also various vegetative supplements are being worked into the soil surface. In some cases the results have been highly encouraging. The cooperators are of the opinion that some important leads have been produced and that continuation of the research will produce a solution to the problem of effecting the recharge of the ground-water aquifers.

WATER TOOK SPOTLIGHT IN OHIO

WATER, one of the great common denominators, holds many answers to our destiny. Water is the great giver of life to plants and animals, and an index to tomorrow's agriculture and industry. Water is important in both molecule and mass. It is of daily concern to physician, farmer, and hydraulic engineer. It is a fluid, a mineral, a gas, a solid—various of form and inconsistent of behavior. Climate, population, economic and social geography, the whole course of civilization, are at the mercy of water. Water has never ceased to command the attention of scientist, philosopher, and poet. But water still is reluctant to reveal its secrets.

Most recent effort to bring water into focus was the Eighth Annual Conference on Conservation, Nutrition, and Health in Athens, Ohio, last June. In cooperation with Ohio University, Friends of the Land brought to the rostrum nearly a score of top-flight authorities to exchange data and ideas pertaining to water and its ways. It was an historic event, one of many bold strokes by which Friends of the Land has won its eminence as an outstanding exponent of the conservation cause. Repercussions of this conference will be felt for many years, for it set in motion a machinery of thought that bears on watershed management, city and country water supplies, drainage and irrigation projects, the future of rivers and harbors, power developments, and human culture.

On the two following pages SOIL CONSERVATION Magazine presents brief summations of several of the addresses. Several other papers will be abstracted in future issues.

—WELLINGTON BRINK.

Next month: An important article by C. W. Lauritzen and O. W. Israelsen, "Canal Linings Tested in Field"

PLAN OR PERISH. (Ohio Conference.)—In the opening address, J. Russell Smith, professor of economic geography, Columbia University, laid emphasis on the dangers involved when water's place in nature's series of balances is disturbed. He cited the fate of the past cultures of Indus and Mesopotamia—cities ruined, abandoned, buried, and forgotten—as examples of what happens when mud gets ahead of man. Modern man, with new equipment, is building dams and tackling the Indus in modern style. How long he will keep ahead of it remains to be seen.

As an appalling example of the general human inability to read history and profit by it, Smith cited the Rio Grande Valley in New Mexico and west Texas.

A large section of the upper Rio Grande Valley drains into the magnificent Elephant Butte Reservoir which was built some years ago, he noted. After having done this, we permit overpasturing to break nature's balance of water-plant-soil. Nibbling beasts destroy the grass in wide almost-level upland valleys. After the sod is broken, gullies start and become little canyons and the fertile soil of the upland valley becomes millions of tons of silt that goes on down to choke the Rio Grande. As a result this river at Albuquerque has so filled its channel with sand, men have built dykes to keep the river from flowing over the valley. That was done years ago. It is still filling up its dyked channel with sand until now the stream bed is higher than the adjacent city. Yet more, the valley which once was good irrigated land can no longer drain into the river. Therefore it becomes waterlogged and farms are being destroyed by alkali, but the river is unable to carry its complete load on down to fill the Elephant Butte Reservoir.

I think this is one of the most perfect examples of regional suicide to be found anywhere in the world. First, we ruin an upland pasture. Second, this ruin causes wash to fill a channel of a river so that men must build artificial banks, dykes. Third, the filling of the channel raises the water table in the valley and irrigated land in the valley is ruined. Fourth, we build a great dam and turn a part of the valley into a reservoir to hold water to irrigate hundreds of thousands of acres farther down, but this needless silting is needlessly filling this beautiful reservoir. Fifth, the filling of this reservoir will stop most of the irrigation in fertile valley lands below and must inevitably turn many towns into roosts, which is the future of an irrigated settlement when the water is gone.

Smith would like to see a more comprehensive examination made of water than has ever before been undertaken.

We have twin problems, both menacing, soil erosion and water scarcity, he observes. Combined, this pair of devils has ruined many a land and their capacity to do this is increasing rather than decreasing now that machines have made man so destructive. Therefore, one of the pressing research needs is for as complete as possible a study of water, or of a river, beginning with the fall of the raindrop, following through their surface flow; rills, rivulets, creeks, rivers, runoff; absorption by soil, retention by soil, loss by evaporation, and all the problems of siltation, channel filling, flood. In other words, a complete study of water, including a complete study of a river. It is one of the pressing jobs which some foundation should take up.

WATER ACCOUNTING. (Ohio Conference.)—Water accounting is old as antiquity, the conference was told by C. V. Youngquist, chief engineer, Ohio Water Resources Board. The Temple of Roda, built by the Arabs at Cairo, Egypt, contained a well connected to the Nile. In this well was a gage of stone graduated in cubits for reading stages of the Nile. This gage has been read continuously since 622 A. D.—13 centuries of water accounting on the River Nile.

Prior to the building of the Roda Temple there are records of gage readings of the River Nile by the Egyptians extending back to 3500 B. C. The Palermo Stone, an ancient Egyptian monument on which were inscribed important events in the life of the Egyptians, contains frequent references to the gage height of the River Nile.

Why did the Egyptians and Arabs build elaborate structures for maintaining water accounts of the River Nile? Because water of the Nile was the very life blood of Egypt. Flow behavior of the Nile meant feast or famine. Water was recognized by this ancient people as their most indispensable and valuable natural resource and as such they were justified in elaborate means for measuring that resource. In fact, the whole economy of Egypt was regulated by the results of water gaging. An optimum gage height on the Nile gage meant a year of bountiful harvest and plenty, not only for Egypt but for much of the known world because Egypt became the world's granary.

Youngquist said that the modern world is beginning to appreciate that water can be a limiting factor to growth of population or industry. Western United States has been conscious of this situation for many years. The task of systematically measuring and accounting for the water resources obtained its greatest stimulus in the West.

The humid Eastern States have lately become conscious of the need of appraising and accounting for their water resources. While the quantity of precipitation may seem adequate, variations in the quantity and its distribution lead to acute problems of drought and flood. To properly cope with these problems requires that a systematic program for observing, measuring, and interpreting all phases of water occurrence in the hydrologic cycle be maintained.

The speaker described various methods being used to obtain water measurements at various points in the hydrologic cycle.

The collection of a vast quantity of data on water is not an end in itself, Youngquist was careful to note. It is the careful sifting and interpreting of such data which results in better understanding of water occurrence, of the quantities available for use and the best methods of utilizing water. There are still large blanks in our knowledge of the hydrologic cycle which will require much research to fill in. The data which have been collected have, however, greatly increased our understanding of water occurrence.

FITTING AGRICULTURE TO RAINFALL. (Ohio Conference.)—The necessity of fitting agriculture to the effective amount and seasonal pattern of rainfall was pointed out by C. W. Thornthwaite, director, Laboratory of Clima-

tology, Johns Hopkins University. He believes that several things can be done to bring water needs and rainfall more nearly together.

Since it is impossible to change the rainfall to fit the water need, changes must be made in other ways, he explained. One possibility is to increase the moisture-storage capacity of the soil. Every added inch of usable water in the soil is as good as an extra inch of rainfall and will delay the onset of drought.

Many farming practices reduce the storage capacity of the soil rather than increase it, Thornthwaite noted. Crop rotations, with the frequent use of grasses and legumes, improve the soil structure and increase its water-storage capacity. This and other conservation practices make the soil more absorptive, and less water is lost by direct runoff when the rains are intense.

A second possibility is to reduce the water needs of the crop. Plants that use less water, or farming practices that increase the efficiency of water use, could minimize drought.

Adjusting the crop calendar to anticipate time of drought, and making up the water deficiency by use of supplementary irrigation, were also suggested as good water-management procedures.

Not only is drought the greatest natural hazard to agriculture, but its stringencies are visited also upon the city dweller, for drought cuts down the quality of produce.

Foods that have suffered from drought are neither so good nor so nutritious as those that have not, Thornthwaite said.

Drought is hard to measure because we are not yet able to determine the water needs of plants very accurately, he concluded. Only when we have learned how to measure the combined evaporation from the soil surface and transpiration from plants, both potential and actual, shall we be able to combat drought intelligently.

WATER DETERMINES FLORA AND FAUNA. (Ohio Conference.)—Over the entire earth's surface available water and soil moisture determines which plants and trees, and what animals will inhabit the region, stated H. L. Shantz, retired head of the wildlife division of the United States Forest Service. Plants, he said, depend on the way they adjust themselves to soil moisture. Animals, in turn, must adjust themselves to the plants.

Most plants must have a constant stream of water passing into their roots . . . into and over each living cell . . . and out again into the air. If this stream is stopped for only a few minutes, many land plants will die. Shantz cited the amount of water passing through 10 fields of alfalfa plants in the middle of a bright summer day as being about a ton of water every 10 seconds.

On the other hand, many desert plants make great adjustments to the scarcity of water. Nature strikes a balance between the amount of moisture, the number and nature of the plants, and the animals which can live in the desert. A similar balance obtains in the ocean.

Shantz declared that the ultimate level of human progress depends upon the climate and the water supply.

It is most fortunate, he remarked, that water is our most abundant mineral. But if we expect to find it where we want it, we must learn to conserve it and to trap the raindrop where it falls.

MOISTURE, FERTILIZER, PLANTS. (Ohio Conference.)—Approximately 1,500 cubic miles of water fall upon the surface of the United States annually, Jackson B. Hester, soil technologist, told the conference.

Hester, in his discussion of soil moisture movements and their influence upon yields and fertilizer needs, said that nearly half of this 1,500 cubic miles of water evaporates and in the neighborhood of one-fourth flows off in the surface stream. The remaining 25 percent works its way into the earth's crust. He estimated that the quantity of ground water within the first hundred feet of surface soil amounts to a layer equivalent to 17 feet of water over the entire surface of this country.

As the water passes by the plant and into the deeper regions of the earth's crust, it carries with it much sodium, chlorine, sulphur, and other excess ions which are not needed for plant growth, but which came in with the fertilizer that was applied, Hester explained. This keeps the soil from becoming too salty and is beneficial for the crop.

It is absolutely necessary to keep plants growing all of the time on soils that are subject to leaching under humid conditions, he contended. This will prevent leaching of the badly needed elements and lessen the movement of water. Furthermore, the plant food tied up in this organic matter would be less subject to leaching during the interim in which the crop is decomposing and a successive crop is being established. Free water can move into the sub-surface soil during such periods without removing large amounts of plant food.

However, Hester observed, our agricultural practices which are geared to a cash economy make it sometimes difficult to follow this practice.

CRITICAL SHORTAGES. (Ohio Conference.)—Water shortages are not a recent development, according to J. V. B. Wells, chief, surface water branch, United States Geological Survey. Temporary and localized shortages have been experienced since our country was first settled.

Records of stream flow and climatological data indicate that, although some trends may be downward, there has been no substantial country-wide change in rainfall and runoff in the past 50 years. Therefore, our present water shortages result mainly from increased consumption.

The crux of the matter, as Wells sees it, is that the use of water had increased out of all proportion to growth of population. Industry, using vast quantities of water for cooling and other purposes, the increasing use of irrigation water in parts of the East to supplement rainfall during critical periods in the growing season, and extensive air-conditioning are just a few of the modern demands for water.

Wells believes that the Nation-wide inventory of surface- and ground-water resources, both as to quantity and to quality, is a prerequisite to understanding and solving water problems.

Our water shortages are disquieting, and in some instances may prove costly to remedy, Wells concluded. Nevertheless, by combining intelligent utilization with adequate basic information, at no time in the foreseeable future need our country's development be hampered by lack of water.

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